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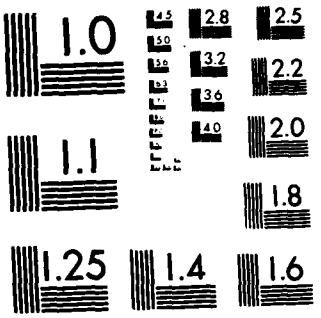

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Progress into research on the interaction of droplets with shock waves, the mixing of co-axial jets in the near region, the influence of nearby solid boundaries on multihole probes, and the behavior of shock trains in ramjet inlets, ~~is described.~~ The study of the mixing of coaxial jets has been completed with the submission of a PhD dissertation. Appropriate software for Laser Velocimetry data reduction has been prepared for use with the droplet-shock wave study, and a computer program for the description of droplet shock wave interaction generated. Preliminary measurements of solid boundary

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influence on five hole probe readings have been taken, and optical data for shock trains in ramjet inlets have been obtained from both a water analogy rig and a supersonic wind tunnel.

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RESEARCH OBJECTIVES

Four major research topics are considered under this grant, the interaction of droplets with shock waves, the mixing of co-axial jets in the near region, the influence of nearby solid boundaries on multihole probes, and the behavior of shock trains in ramjet inlets. Detailed discriptions of the topics are given in the following.

1 Interaction of droplets with shock waves.

The presence of large amounts of condensate in the flow entering a transonic fan has been found to seriously affect the fan performance. This study is directed towards the detailed understanding of the interaction of water droplets with severe pressure gradients, including shock waves. The study includes both the theoretical and experimental description of droplet clouds interacting with shock waves and severe pressure gradients.

2 Mixing of co-axial jets in the near flow region.

The use of a large (8") diameter pipe allows the detailed study of the mixing behavior of co-axial jets in the near region of the flow. Consideration of several flow conditions (stagnation pressure ratio of the two streams) and of two different imposed axial pressure gradients, has allowed aquisition of detailed information concerning the behavior of the mean flow field as well as the Reynolds stress field. The latter measurements include the degree of anisotropy of the turbulence. Aquisition of such data leads to understanding of the turbulent interactions as well as providing useful test cases for computational predictive techniques.

3 The influence of nearby solid boundaries on multi-hole probes.

Partly because of the availability of high rate data processing capability, multi-hole probes are enjoying a rebirth in popularity for measurement of fluid properties in flows of large skewness angles. Often,

however,the accuracy of such measurements is compromised because of the induced effects of a nearby solid boundary. It is planned to investigate the effect upon probe calibration of nearby solid boundaries with the objective of generating calibration techniques appropriate for use in such flow situations, and to develop scaling laws to aid in the prediction of such effects.

4 Behavior of shock trains in ramjet inlets.

Ramjet inlets are usually of such small size that the use of variable geometry and boundary layer suction is not feasable. In such cases, the fluid entering the almost constant area portion of the inlet diffuser usually has a large wall boundary layer. As a result, the shock wave system occupies a substantial length within the inlet, and it is difficult to predict the design behavior of the system.

It is planned to investigate with both Schlieren apparatus and flow table analogues, the behavior of shock trains in such inlets. The objective is to acquire physical insight into the phenomenon, and to generate an appropriate analytical model for the interaction.

STATUS OF THE RESEARCH EFFORT

1 Interaction of droplets with shock waves.

It is unfortunate that progress on this study was substantially hampered by electronic difficulties in the laser velocimeter data processing equipment. The source of the problems has now been identified (intermittent short in the power supply), and the data processing system and related software has been checked out and tested on simple flow examples. Measurements on realistic shock-droplet interactions will be carried out in the near future.

A time marching numerical program for calculating flow fields with interacting droplets and shock waves has been written and checked out. The program runs successfully, but at present requires a good estimate of particle slip velocity throughout the flowfield. (This is a reflection of the fact that if the particle slip velocities are incorrect by only small amounts. the corresponding effective body forces are extremely large). Techniques will be introduced to make the program more stable to errors in the assumed initial conditions.

2 Mixing of co-axial jets in the near flow region

The first phase of this study has been completed with the submission and acceptance of the Ph.D. dissertation, "Investigation of Axisymmetric Confined Turbulent Jet Mixing in the Near Region with Adverse Pressure Gradient" by Dong Whan choi. Two papers have been prepared and submitted to the ASME for publication and presentation.

3 The influence of nearby solid boundaries on multi-hole probes.

Calibration procedures, and the related data reduction programs for use with five hole probes have been further developed and checked out. Several test series have been run with the probe in the near vicinity of a flat plate (which itself has only a small boundary layer). The data shows a pronounced

effect of the increased velocity about the probe caused by the presence of the wall. It is intended to complete some further series of tests, and then to attempt to identify appropriate scaling laws or analytical predictive techniques to allow use of such probes near solid boundaries.

4 Behavior of shock trains in ramjet inlets.

A series of optical flow studies were conducted using a free surface water table flow analogy to represent the compressible flow field of a ramjet inlet. The many photographs show that the qualitative behavior of the flow is well represented. It is apparent, however, that the free surface water table techniques will remain qualitative,only,in that "shock waves" actually appear as a family of waves (probably identified with various layers of the shear layer), and as a result limit the accuracy of the simulation.

Accurate representation has been obtained using a drawdown wind tunnel to provide the inlet entrance flow. The scale of the model is such, however, that the finer details of the flowfield are difficult to resolve. Further investigations are planned in which glass sidewalls (rather than plastic) are employed. Preliminary studies indicate that the better optics provided by glass sidewalls lead to substantial improvement in the photographic resolution.

Preliminary analytical efforts have been directed to describing the shock train interaction by representing the flow field in terms of a "compound flow" with three identifiable layers. The intent is to create a model that captures, in as simple a manner as possible, the fundamental mechanism by which multiple normal shock waves may be generated.

Cumulative Chronological List of Written Publication in Technical Journals.

- No publications in technical journals have yet appeared.

Dissertation.

- Investigation of Axisymmetric Confined Turbulent Jet Mixing in the Near Region with Adverse Pressure Gradient.

  Dong Whan Choi, Ph.D. Thesis, June 1983, University of Washington.

List of the Professional Personnel Associated with the Research Effort.

- Gordon C. Oates - Professor and Principal Investigator.
- Fred B. Gessner - Professor.
- Dong Whan Choi - Ph.D. student (graduated).
- Roger K, Nicholson - Ph.D. student and research assistant.
- T. Tamigniaux - M. Eng. student and research assistant.
- M. Naimi - Post Masters student and research assistant.

Interactions (Coupling Activities)

- None.